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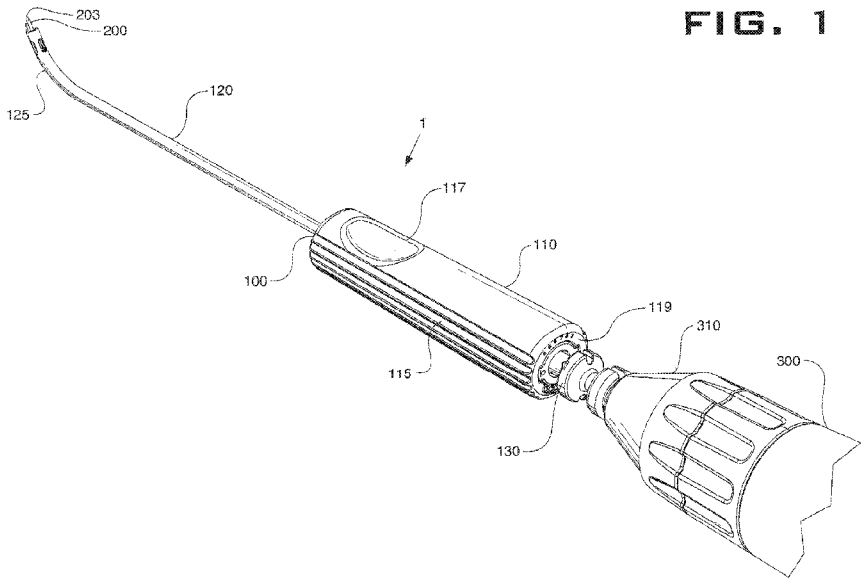
(54) Title: MULTI-DEPTH DRILL STOP AND METHOD OF DRILLING

FIG. 1



(57) Abstract: Embodiments of the invention include instruments (1, 1001) and methods for drilling a hole to a predetermined depth. Some embodiments may include adjusting the length of a drill stop (100, 400) through which a drill bit (200, 240, 1200) is passed, and by adjusting the length of the drill stop (100, 400), controlling the depth beyond a distal end of the drill stop (100, 400) that a distal end of the drill bit (200, 240, 1200) is allowed to extend and penetrate tissue against which the distal end of the drill stop (100, 400) is placed.

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MULTI-DEPTH DRILL STOP AND METHOD OF DRILLING

FIELD OF THE INVENTION

[0001] The present invention relates generally to the field of medical devices, and more particularly relates to instruments and methods for drilling a hole in tissue to a predetermined depth. Some embodiments use an adjustable length drill stop to control the depth of penetration of a drill bit beyond the drill stop.

BACKGROUND

[0002] It is often useful in the performance of surgical procedures to drill holes in tissue to a predetermined depth beyond a distal end of a drill guide. Many drill guides with depth stops have been designed for use in such procedures. Endoscopic, percutaneous, and minimally invasive procedures often require relatively far extending drilling of holes in tissue, and further may restrict a user's ability to visualize or manipulate a distal end of a drill guide. Some procedures may further benefit from a guide and depth stop that is capable of bending a drill bit along its length to align drilling in a desired direction.

[0003] It would be advantageous to provide a drill guide or drill stop that allows for drill bit depth adjustment to a predetermined depth beyond a distal end of the drill guide or drill stop without requiring access to a distal end of the drill guide or drill stop. It may be further advantageous to provide for depth adjustment with a mechanism located solely near the proximal end of the drill guide or drill stop. An improved device may also include a curved portion through which a flexible drill bit may be inserted and rotated. Improved devices may also include indicators at one or more locations along the length of a drill guide or drill stop that display for a user an amount of extension or potential extension of a drill bit beyond a distal end of the drill guide or drill stop.

SUMMARY

[0004] An embodiment of the invention is a drill stop that includes a body, a cannula coupled to a distal end of the body, and a knob. The knob may be adjustably

coupled to a proximal end of the body and movable relative to the body to alter the length of the drill stop. In some embodiments, the drill stop includes a passage that passes through the cannula, the body, and the knob.

[0005] Another embodiment of the invention is a drilling system that includes a drill stop, a drill bit, and a drill. The drill stop of some embodiments includes a body, a cannula coupled to a distal end of the body, and a knob adjustably coupled to a proximal end of the body and movable relative to the body to alter the length of the drill stop. The drill bit of some embodiments includes a drill bit sized to pass through the drill stop. The drill of some embodiments includes a drill with a drill chuck configured to couple to the drill bit. The drill chuck may include a distal face configured to contact and be limited by a portion of the drill stop.

[0006] Still another embodiment of the invention is a drilling system that includes a drill stop and a drill bit. The drill stop may include a body, a cannula coupled to a distal end of the body, and a knob adjustably coupled to a proximal end of the body and movable relative to the body to alter the length of the drill stop. The drill bit may be sized to fit within the drill stop and restricted from moving beyond a predetermined point relative to the knob by a limiter portion of the drill bit configured to contact a limiting surface of the knob.

[0007] Yet another embodiment of the invention is a method of drilling a hole to a predetermined depth. Method embodiments may include coupling a drill bit to a drill chuck at a predetermined location such that a distal end of the drill bit extends a predetermined length beyond a distal face of the drill chuck, and adjusting a drill stop that includes a passage through which the drill bit is sized to pass to a length. The length of the drill stop may be less than the predetermined length that the distal end of the drill bit extends beyond the distal face of the drill chuck. Method embodiments may also include advancing the drill bit through the drill stop until the distal end of the drill bit extends out of the drill stop.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a perspective view of an embodiment of a drilling system.

[0009] FIG. 2 is a perspective view of a portion of the drilling system that shows a drill stop and drill bit of the drilling system of FIG. 1.

[00010] FIG. 3 is a perspective view of a drill chuck and a portion of the drill bit of the drilling system of FIG. 1.

[00011] FIG. 4 is a side, broken elevation view of the drill bit of the drilling system of FIG. 1.

[00012] FIG. 4A is a side elevation view of distal end of an alternate drill bit with a different distal tip from the drill bit of FIG. 4.

[00013] FIG. 5 is an exploded perspective view of the drill stop of the drilling system of FIG. 1.

[00014] FIG. 6 is an enlarged perspective view of a distal end of a cannula of the drill stop of the drilling system of FIG. 1.

[00015] FIG. 7 is a proximal end elevation view of a body of the drill stop of the drilling system of FIG. 1.

[00016] FIG. 8 is a side elevation view of a knob of the drill stop of the drilling system of FIG. 1.

[00017] FIG. 9A is a proximal end elevation view of the body and knob of the drill stop of the drilling system of FIG. 1 with the drill stop in an expanded state and excluding a drill chuck shown n figure 9B.

[00018] FIG. 9B is a side elevation view of the body and knob of FIG. 9A and additionally showing the drill chuck.

[00019] FIG. 9C is a side elevation view of the distal end of the cannula and a distal end of the drill bit of the drilling system of FIG. 1 in the expanded state of FIG. 9A.

[00020] FIG. 10A is a proximal end elevation view of the body and knob of the drill stop of the drilling system of FIG. 1 with the drill stop in a contracted state and excluding a drill chuck shown in FIG. 10B.

[00021] FIG. 10B is a side elevation view of the body and knob of FIG. 10A and additionally showing the drill chuck.

[00022] FIG. 10C is a side elevation view of the distal end of the cannula and a distal end of the drill bit of the drilling system of FIG. 1 in the contracted state of FIG. 10A.

[00023] FIG. 11 is a perspective view of an alternate body and knob embodiment.

[00024] FIG. 12 is a cross-sectional view of the alternate body and knob of FIG. 11.

[00025] FIG. 13 is an exploded perspective view of the alternate body and knob of FIG. 11.

[00026] FIG. 14 is a perspective view of a portion of the alternate knob of FIG. 11.

[00027] FIG. 15 is a perspective view of an embodiment of a drilling system.

[00028] FIG. 16 is a cross-sectional perspective view of the drilling system of FIG. 15.

[00029] FIG. 17 is an enlarged view of the proximal end of the cross-sectional perspective view of the drilling system of FIG. 16.

[00030] FIG. 18 is a perspective view of a drill bit of the drilling system of FIG. 15.

DETAILED DESCRIPTION

[00031] A drilling system 1 and its component parts are illustrated collectively, separately, and in different states of operation in FIGS. 1-10C. The assembled drilling system 1 is shown in FIG. 1 with a drill stop 100, a drill bit 200, and a drill 300. The drill stop 100, as shown in whole or in part in FIGS. 1, 2, and 5-10C includes a body 110, a cannula 120 coupled to a distal end 112 of the body 110, and a knob 130 adjustably coupled to a proximal end 114 of the body 110 and movable relative to the body 110 to alter the length of the drill stop 100.

[00032] The drill bit 200 of some embodiments is depicted in FIGS. 1-4, 9C, and 10C sized to pass through the drill stop 100. The drill bit 200 is shown in FIG. 4 with a proximal end 201 and a distal end 203. A bushing 205 is illustrated near the distal end 203. The bushing 205 is configured to be moved along an inside diameter of the cannula 120 and assist with centering the distal end 203 of the drill bit 200 relative to the cannula 120. The bushing 205 of various embodiments may permit rotation between one or both of an outside diameter of the bushing 205 an the inside diameter of the cannula 120, and the bushing 205 relative to an inner shaft 207 of the drill bit 200. The bushing 205 of some embodiments may include a flexible coupling between portions of the drill bit 200 proximal and distal of the bushing 205. For example and without limitation, the bushing 205 may be flexible, may contain a U-joint, or may include a variable angle torque transfer gear system. All or any portion of the drill bit 200 may be flexible by any effective mechanism. For example and without limitation, the drill bit 200 or any portion of it, may be constructed from a relatively flexible material, may be made from a helically wound wire, or may include one or more cuts along the length of the drill bit that allow the drill bit to flex laterally while still transferring torque when rotated.

[00033] Embodiments of the drill bit 200 may include a marking 210 (FIGS. 2-4) to designate where a drill chuck 310 of the drill 300 is to be coupled to the drill bit 200. A drill chuck 310 is specifically shown coupled to the drill bit 200 at the marking 210 in FIG. 3. The drill bit 200 also includes the text, "END OF DRILL CHUCK" adjacent to the marking 210 to assist a user with properly aligning the drill bit 200 relative to the drill chuck 310. As particularly shown with this embodiment, a distal face 313 (FIG. 3) is shown aligned with the marking 210. The distal face 313 illustrated is configured to contact and be limited by a proximal portion of the knob 130, as illustrated in FIGS. 1, 9B, and 10B. Other embodiments may include other alignments with other shapes of drill chucks in any configuration that enables a drill chuck to form a consistent interaction with a cooperating drill stop.

[00034] A distal portion of an alternate drill bit 1200, as shown in FIG. 4A, may have a bushing 1205 near a distal end 1203 of the drill bit 1200. The bushing 1205 is substantially spherical, but may be other effective shapes in other embodiments. The bushing 1205 is configured to be moved along the inside diameter of the cannula 120 and assist with centering the distal end 1203 of the drill bit 1200 relative to the cannula 120. The bushing 1205 of various embodiments may permit rotation between

one or both of an outside diameter of the bushing 1205 an the inside diameter of the cannula 120, and the bushing 1205 relative to an inner shaft 1207 of the drill bit 1200. The bushing 1205 of some embodiments may include a flexible coupling between portions of the drill bit 1200 proximal and distal of the bushing 1205. More than one spherical bushing may be included along a length of some drill bits.

[00035] The drill 300 may be any functional rotating or plunging mechanism capable of coupling with a drill bit and turning or otherwise advancing the drill bit or other hole forming instrument distally. The drill 300 shown in FIG. 1 is configured to rotate the drill chuck 310 and the drill bit 200, 1200. A drill of various embodiments may be rotated or otherwise moved by a mechanism driven by electrical energy, whether hard wired or battery powered, pneumatic pressure, liquid pressure, manual operator-provided force, or any other effective energy source. The drill 300, or any other drill embodiment, may be torque limited and rotary speed may be generally adjustable and may be limited to a maximum speed.

[00036] The drill stop 100 illustrated in FIGS. 1, 2, and 5-10C includes the body 110 that is also a handle for grasping by an operator or other instrument. The body 110 shown is used to position the drill stop 100 relative to a patient's anatomy to accomplish a surgical task. The body 110 includes surface features 115 in the form of longitudinal ridges and grooves to facilitate grasping of the body 110. Any other effective shape or feature may be used to facilitate grasping of this or a similar body. For example and without limitation, a body of various embodiments may be ergonomically shaped to fit into the hand or against the fingers of an operator, may include knurling, ridges, depressions, coatings, texture, or inlayed portions. The illustrated embodiment also includes a surface feature in the form of a thumb grip 117 shown in FIGS. 1, 2, and 5.

[00037] The cannula 120 is shown in FIGS. 1, 2, 5, 6, 9C, and 10C. A proximal end 121 of the cannula 120 (FIG. 5) is configured to couple to the distal end 112 of the body 110. The particular embodiment of the proximal end 121 illustrated includes a section with a knurled surface 122 that promotes coupling between the handle 110 and the cannula 120 within an opening 111 within the body 110. Embodiments of a handle and cannula may include any effective mechanism, interface, adhesive, welding, melting or other action or substance to couple a cannula and a handle together. The coupling between the handle 110 and the cannula 120 may be permanently fixed or removable in various embodiments. The cannula 120 is an

elongated member with a length that is greater than ten times its own diameter. Other embodiments may include greater or lesser length to diameter ratios.

[00038] The cannula 120 includes a curved portion 125 near its distal end 123. The curved portion 125 is a single curve of approximately 60 degrees, but other embodiments may include multiple curves and curves of greater or lesser amounts. One or more curves of various embodiments may be particularly arranged to provide access to specific surgical sites. Some embodiments of a cannula may be substantially straight from their distal to their proximal ends.

[00039] As most clearly seen in FIGS. 6, 9C, and 10C, the cannula 120 includes windows 128 through which an indication 244, 299 on the drill bit 200, 1200 of the amount of extension of the drill bit 200, 1200 beyond the distal end 123 of the cannula 120 may be viewed. Specifically, where a line, color, number, or other marking is placed on a drill bit, the indication or marking may be visible through one or more of the windows 128. Such a marking may be visualized directly by a user or visualized through an optical scope, camera, or other viewing device or sensor. Windows may be placed at one or more locations along a drill stop to view pre-positioned, correlating markings on a drill bit indicating the amount of extension of the drill bit beyond a distal end of a cannula relative to the windows and markings. The indication 244 (FIG. 9C) of the illustrated embodiment includes a number "4" adjacent to a marking proximal of the number. Markings on the drill bit 200, 1200 are configured to align adjacent to a line 127 placed on the cannula 120. Additional markings on the drill bit 200, 1200 are placed at 1mm increments so that a user may count from the 4mm marking to determine additional depths. The indication 299 (FIG. 10C) of the illustrated embodiment includes a number "9" adjacent to a marking distal of the number. The indication 299 is at the opposite end of the markings placed at 1mm increments noted above. A user may similarly count down from the 9mm marking to determine additional depths.

[00040] The cannula 120 depicted also includes a spike 129 (FIGS. 6, 9C, and 10C) that may be used to fix a location of the cannula relative to tissue into which a hole is to be created. The spike 129 has a triangular shape, but other embodiments may be of any effective shape. The spike 129, or spikes of some other embodiments, may be assumed to be pushed into tissue in which a hole is going to be created, and therefore would not have its length counted as part of the distal end length beyond which a hole is to be created to a predetermined, measured depth. In other

embodiments, the spike 129, or another spike, may be configured to not fully penetrate tissue, and therefore, all or a part of the spike's length may be counted as part of the distal end length beyond which a hole is to be created to a predetermined, measured depth.

[00041] The knob 130 shown in FIGS. 1, 2, 5, 8, 9A, 9B, 10A, and 10B is generally round in a cross-section through its longitudinal axis and is configured to be rotated relative to the body 110 to alter the length of the drill stop 100. In other embodiments, a knob may be of any effective shape that couples to a body and moves relative to the body to alter the combined length of the knob and the body. The knob 130 is adjustably coupled to a proximal end 119 of the body 110 and movable relative to the body 110 to alter the length of the drill stop 100. The knob 130 shown is configured to be rotated relative to the body 110 to alter the length of the drill stop 100. In particular, the knob 130 is configured to be pulled proximally to remove a pin 135 (FIGS. 5, 8, 9B, and 10B) that is fixed to the knob 130 from one of a number of stair step holes 1104, 1105, 1106, 1107, 1108, 1109 (FIG. 7) in the proximal end 119 of the body 110 to thereby release the knob 130 to rotate relative to the body 110. Each of the stair step holes 1104, 1105, 1106, 1107, 1108, 1109 depicted is of a different depth. In the illustrated embodiment, the stair step holes 1104, 1105, 1106, 1107, 1108, 1109 are incrementally 1mm different depths, with the hole 1104 being the shallowest and the hole 1109 being the deepest.

[00042] In some embodiments, the pin 135 may be referred to as a following member that may be moved to different steps in a stair step type structure such as the stair step holes 1104, 1105, 1106, 1107, 1108, 1109. By moving the pin 135 to different steps, the length of a drill stop may be adjustably altered. Other stair step type structures may not include holes, but may include only treads of the stairs spaced laterally apart by risers of the stairs. In some embodiments, one or more step landings of the stair steps may include an indention for receiving a portion of a following member to resist rotational movement between the body and the knob. Some embodiments may include multiple following members that interact with complementary following members on a knob or a body. For example, a stair step structure on a knob may interact with a complementary stair step structure on a body such that at each increment of adjustment one, two, or more of the complementary stair steps interact. In some embodiments, a stair step structure may only be located on a knob, and a following member may be located on a body. The knob 130 may be

spring biased toward the body 110 in some embodiments. In such a configuration, the pin 135 would be urged toward a respective bottom of one of the stair step holes 1104, 1105, 1106, 1107, 1108, 1109 to maintain a set length when the knob 130 is released. In other embodiments with a different interface between a knob and a body, the knob may be biased away from the body such that adjustment of the length of a drill stop would involve pushing and rotating rather than pulling and rotating, as shown in the illustrated embodiment. Any other effective adjustment mechanism between a knob and a body may be used in other embodiments. For example and without limitation, adjustment may be accomplished by a cam mechanism, a thread-driven interface, a rack and pinion mechanism, a slip and lock mechanism, or any combination of these or other mechanisms.

[00043] As most clearly illustrated in FIGS. 7, 8, 9A and 10A, the drilling system 1, and more particularly the drill stop 100, may include an indicator system that indicates the amount of potential extension of a drill bit 200, 1200 beyond the distal end 123 of the cannula 120. The illustrated embodiment of the indicator system includes portions on both the knob 130 and the body 110. Particularly, depth indicators 1114, 1115, 1116, 1117, 1118, 1119 are located on a proximal end 119 of the body 110 and a pointer 136 is located on the knob 130. The depth indicators 1114, 1115, 1116, 1117, 1118, 1119 correlate with settings of predetermined drilling depths of 4mm, 5mm, 6mm, 7mm, 8mm, and 9mm respectively. Other cooperating components of an indicator system may be arranged in any effective order in other embodiments. For example and without limitation, depth indicators may be placed on a knob and a pointer may be placed on a body in some embodiments.

[00044] An example adjustment of the drilling system 1 is illustrated in FIGS. 9A-10C. In FIGS. 9A-9C components of the drill stop 100 and the drill bit 200, 1200 are shown in a relatively expanded state where the distal end 203 of the drill bit 200, 1200 has the potential to extend 4mm beyond the distal end 123 of the cannula 120. The distal end 203, 1203 of the drill bit 200, 1200 is shown extending 4mm beyond the distal end 123 of the cannula 120 in FIG. 9C with the drill chuck 310 contacting the knob 130. In FIG. 9A, the pointer 136 is shown aligned with the depth indicator 1114. The pin 135 is located in hole 1104 (FIG. 7) in the proximal end 119 of the body 110 with the drill stop 100 in its relatively expanded state as illustrated. By pulling the knob 130 away from the body 110 and rotating the knob 130 until the pointer 136 aligns with the depth indicator 1119, as shown in FIG. 10A, the drill stop

100 will contract to a relatively shorter length when the knob 130 is released by a user and the pin 135 enters the relatively deeper hole 1109 (FIG. 7). The shorter length of the drill stop 100 is most clearly shown in FIG. 10B. The distal end 203, 1203 of the drill bit 200, 1200 is shown extending 9mm beyond the distal end 123 of the cannula 120 in FIG. 10C with the drill chuck 310 contacting the knob 130. This results from the drill bit 200, 1200 being passed through a relatively shorter drill stop 100, but where the drill bit 200, 1200 and drill chuck 310 have maintained the same relationship as illustrated in FIGS. 9A-9C.

[00045] In the illustrated embodiment, the drill stop 100 includes a passage that extends through the cannula 120, the body 110, and the knob 130. The passage of the illustrated embodiment passes substantially through the geometric center or cross-section of each of the cannula 120, the body 110, and the knob 130. Some embodiments of the cannula 120, the body 110, and the knob 130 may include an offset passage. In other embodiments, a passage may only extend through one or more of these or other similar portions of a drill stop and bypass some portions.

[00046] An alternate knob 630 and the body 610 are illustrated in FIGS. 11-14. In such embodiments, the cannula 120, drill bit 200, 1200, and the drill 300 are substantially the same as described herein for the drilling system 1, but the knob 630 and the body 610 include different mechanisms, which are described here.

[00047] The knob 630 shown in FIGS. 11-13 is generally round in a cross-section through its longitudinal axis and is configured to be rotated relative to the body 610 to alter the length of the drill stop of which they are a part. In other embodiments, a knob may be of any effective shape that couples to a body and moves relative to the body to alter the combined length of the knob and the body. The knob 630 is adjustably coupled to a proximal end 619 of the body 610 and movable relative to the body 610 to alter the length of the drill stop. The knob 630 includes a head 631 and a stem 632 that fit together and rotate and translate relative to the body 610. A spring 633 (FIGS. 12, 13, 16 and 17) is positioned between the body 610 and the stem 632 of the knob 630 to provide a biasing force that urges the knob 630 distally relative to the body 610. In other embodiments with a different interface between a knob and a body, the knob may be biased away from the body such that adjustment of the length of a drill stop would involve pushing and rotating rather than pulling and rotating, as shown in the illustrated embodiment. In the illustrated embodiment, the head 631 and the stem 632 are coupled together around the proximal end 619 of the body 610 at a

joint 634 (FIG. 12). The joint 634 may be formed by any effective mechanism, including but not limited to, an adhesive, a mechanical connector, ultrasonic welding, or by a fastener passed through the head 631 and into the stem 632. The knob 630 shown is configured to be rotated relative to the body 610 to alter the length of the drill stop. In particular, the knob 630 is configured to be pulled proximally to remove a following member 635 (FIG. 14) that is fixed to the head 631 of the knob 630 from one of a number of stair step indents 1604, 1605, 1606, 1607, 1608, 1609 (FIG. 13) near the proximal end 619 of the body 610 to thereby release the knob 630 to rotate relative to the body 610. Each of the stair step indents 1604, 1605, 1606, 1607, 1608, 1609 depicted is of a different depth in which the following member 635 may rest to set the length of the drill stop. The stair step indents 1604, 1605, 1606, 1607, 1608, 1609 shown in FIGS. 12 and 13 are for receiving a portion of the following member 635 to resist rotational movement between the body and the knob. In the illustrated embodiment, the stair step indents 1604, 1605, 1606, 1607, 1608, 1609 are incrementally 1mm different depths or distances.

[00048] Other stair step type structures may not include steps with indents, but may include only holes or treads on the stairs spaced laterally apart by risers of the stairs. Some embodiments may include multiple following members that interact with complementary following members on a knob or a body. For example, a stair step structure on a knob may interact with a complementary stair step structure on a body such that at each increment of adjustment one, two, or more of the complementary stair steps interact. In some embodiments, a stair step structure may only be located on a knob, and a following member may be located on a body. Any other effective adjustment mechanism between a knob and a body may be used in other embodiments. For example and without limitation, adjustment may be accomplished by a cam mechanism, a thread-driven interface, a rack and pinion mechanism, a slip and lock mechanism, or any combination of these or other mechanisms.

[00049] The drill stop illustrated in FIGS. 11-15 includes an indicator system that indicates the amount of potential extension of a drill bit 200, 1200 beyond the distal end of the cannula, as described herein. The illustrated embodiment of the indicator system includes portions on both the head 631 of the knob 630 and the body 610. Particularly, depth indicators 1614, 1615, 1616, 1617, 1618, 1619 are located near a proximal end 619 of the body 610 and a pointer 636 is located on the head 631 of the knob 630. The depth indicators 1614, 1615, 1616, 1617, 1618, 1619 correlate with

settings of predetermined drilling depths of 4mm, 5mm, 6mm, 7mm, 8mm, and 9mm respectively. Other cooperating components of an indicator system may be arranged in any effective order in other embodiments. For example and without limitation, depth indicators may be placed on a knob and a pointer may be placed on a body in some embodiments.

[00050] A drilling system 1001 and its component parts are illustrated collectively, and separately, in FIGS. 15-18. The assembled drilling system 1001 is shown in FIG. 15 with a drill stop 400 and a drill bit 240. The drill stop 400, as shown in whole or in part in FIGS. 15-17 includes a body 610, a cannula 420 coupled to a distal end of the body 610, and a knob 630 adjustably coupled to a proximal end of the body 610 and movable relative to the body 610 to alter the length of the drill stop 400.

[00051] The drill bit 240 of some embodiments is depicted in FIGS. 15-18 and is sized to fit within the drill stop 400 and is restricted from moving beyond a predetermined point relative to the knob 630 by a limiter portion 246 of the drill bit 240 configured to contact a limiting surface 637 of the knob 630. Note that the body 610 and the knob 630 are the same as the body 610 and the knob 630 described herein in association with FIGS. 11-14, and their structure and operation will not be described here again except with regard to interactions with the drill bit 240. In particular, as illustrated in FIGS. 16 and 17, longitudinal movement of the drill bit 240 is restricted between the limiting surface 637 and a distal side of the head 631 due to the limiter portion 246 of the drill bit 240 having a larger diameter than a proximal shaft 249 of the drill bit 240. The drilling system 1001 illustrated in FIGS. 15-18 may be a disposable unit. This may be advantageous in keeping the drill bit sharp and effective, to avoid cleaning difficulties and ensure sterility, and to prevent fatigue and breakage of the drill bit due to flexing required at locations such as curved portion 425 (FIGS. 15 and 16). The drilling system 1001 illustrated may be assembled by coupling the cannula 420 to a distal end cap 612, inserting the drill bit 240 through the stem 632 and through the cannula 420 that has been coupled to the end cap 612. The spring 633 may then be place around the stem 632 and then this entire assembly may be moved proximally through the body 610 until a proximal end of the stem 632 is brought into contact with the distal side of the head 631, and the distal end cap 612 is brought into contact with the body 610. Coupling of any effective type may then be accomplished at the joint 634 and between the distal end cap 612 and the body 610 for complete assembly. Any other effective alternate knob drill stop combination may be

used in other embodiments. For example and without limitation, the drill stop 100 and knob 130 may be adapted in some embodiments as part of a modular, disposable drilling system.

[00052] The drill bit 240 illustrated includes a proximal end 241 and a distal end 243. A bushing 245 (FIGS. 16 and 18) is illustrated near the distal end 243. The bushing 245 is configured to be moved along an inside diameter of the cannula 420 and assist with centering the distal end 243 of the drill bit 240 relative to the cannula 420. The bushing 245 of various embodiments may permit rotation between one or both of an outside diameter of the bushing 245 an the inside diameter of the cannula 420, and the bushing 245 relative to an inner shaft 247 of the drill bit 240. The bushing 245 is substantially spherical, but may be other effective shapes in other embodiments. More than one spherical bushing may be included along a length of some drill bits. Bushings of some embodiments may include a flexible coupling between portions of the drill bit proximal and distal of the bushing. For example and without limitation, some embodiments of the bushing may be flexible, may contain a U-joint, or may include a variable angle torque transfer gear system. All or any portion of embodiments of a drill bit may be flexible by any effective mechanism. For example and without limitation, the drill bit or any portion of it, may be constructed from a relatively flexible material, may be made from a helically wound wire, or may include one or more cuts along the length of the drill bit that allow the drill bit to flex laterally while still transferring torque when rotated.

[00053] The drill stop 400 illustrated in FIGS. 15-17 includes the body 610 that is also a handle for grasping by an operator or other instrument. The body 610 shown is used to position the drill stop 400 relative to a patient's anatomy to accomplish a surgical task. The body 610 includes surface features 615 to facilitate grasping of the body 610. Any other effective shape or feature may be used to facilitate grasping of this or a similar body. For example and without limitation, a body of various embodiments may be ergonomically shaped to fit into the hand or against the fingers of an operator, may include knurling, ridges, depressions, coatings, texture, or inlayed portions.

[00054] The cannula 420 is shown in FIGS. 15-17. A proximal end 421 of the cannula 420 (FIGS. 16 and 17) is configured to couple to the distal end of the body 610. Embodiments of a handle and cannula of various embodiments may include any effective mechanism, interface, adhesive, welding, melting or other action or

substance to couple a cannula and a handle together. The coupling between the handle 610 and the cannula 420 may be permanently fixed or removable in various embodiments. The cannula 420 is an elongated member with a length that is greater than ten times its own diameter. Other embodiments may include greater or lesser length to diameter ratios.

[00055] The cannula 420 includes a curved portion 425 near its distal end. The curved portion 425 is a single curve of approximately 60 degrees, but other embodiments may include multiple curves and curves of greater or lesser amounts. One or more curves of various embodiments may be particularly arranged to provide access to specific surgical sites. Some embodiments of a cannula may be substantially straight from their distal to their proximal ends. The cannula 420 and drill bit 240 may include windows and markings as described in association with the cannula 120 and drill bits 200, 1200 herein for the purpose of indicating drilling depth. Additionally, the cannula 420 may include a spike substantially similar to the spike 129 described in association with the cannula 120 and all variations described.

[00056] Some embodiments of the drilling system 1001 may include a drill, such as the drill 300, described herein in association with FIGS. 1 and 3 with all of the features described. However, in some embodiments a distal end of the drill chuck 310 would not need to be configured to contact a proximal portion of a drill stop because the limiter portion 246 of the drill bit 240 in combination with the knob 630 may effectively limit depth penetration of the drill bit 240.

[00057] A method embodiment of the invention is a method of drilling to a predetermined depth. Acts of the embodiment include coupling a drill bit, such as the drill bit 200, 1200, to a drill chuck, such as the drill chuck 310, such that a distal end of the drill bit, such as the distal end 203, 1203, extends a predetermined length beyond a distal face of the drill chuck, such as the distal face 313. Method embodiments may also include adjusting a drill stop, such as the drill stop 100, which includes a passage through which the drill bit 200, 1200 is size to pass to a length. The length of the drill stop 100 to which an adjustment is made is less than the predetermined length that the distal end of the drill bit 200, 1200 extends beyond the distal face 313 of the drill chuck 310. The length of the drill stop is not necessarily a straight line distance. The length of the drill stop 100 may include a path along one or more curves of the cannula 120 or another component of another embodiment. In the illustrated embodiment, the cannula 120 includes the curved portion 125 and the

length referred to here is the length straight through the knob 130 and the body 110, and along the straight and continuing curved portion 125 of the cannula 120. As illustrated, for example in the state change from FIGS. 9A-9C to FIGS. 10A-10C, the act of adjusting the drill stop 100 to a length may include turning the knob 130 of the drill stop 100 relative to the body 110 of the drill stop 100. As noted in the detailed description of the device above, the act of adjusting the drill stop 100 may include pulling the knob 130 away from the body 110 before turning the knob 130. Any other effective mechanism or act of adjusting the length of a drill stop of various embodiments may be used.

[00058] Another act of some embodiments may include placing a distal end of a drill stop, such as the distal end 123, adjacent to tissue. Where a distal end includes a spike or other attachment portion, such as the spike 129 (FIGS. 5, 6, 9C and 10C), the attachment portion may be pushed into the tissue in some embodiments prior to drilling into the tissue. When the cannula 120 is in positon, method embodiments include advancing the drill bit, such as the drill bit 200, 1200, through the drill stop, such as the drill stop 100, until the distal end 203 of the drill bit extends out of the drill stop. The amount of extension out of the drill stop is predetermined by the length of the drill bit to the distal face of the drill chuck compared to the length of the drill stop from the proximal end of the knob to the distal end of the cannula.

[00059] Where a hole has been drilled in tissue with the drill stop at a first setting that is not the drill stop's deepest setting, some method embodiments may include shortening the length of the drill stop to allow a deeper hole to be drilled. This act of shortening may be accomplished with embodiments of the disclosed device without removing distal portions of the device from a patient prior to making an adjustment. For example, a user may refer to the indicator system on the proximal end 119 of the body 110 or may observe the depth of drilling by viewing the extension of the drill bit 200, 1200 through one or more of the windows 128.

[00060] Various embodiments of a system wholly or its components individually may be made from any biocompatible material. For example and without limitation, biocompatible materials may include in whole or in part: non-reinforced polymers, reinforced polymers, metals, ceramics, adhesives, reinforced adhesives, and combinations of these materials. Reinforcing of polymers may be accomplished with carbon, metal, or glass or any other effective material. Examples of biocompatible polymer materials include polyamide base resins, polyethylene, Ultra High Molecular

Weight (UHMW) polyethylene, low density polyethylene, polymethylmethacrylate (PMMA), polyetheretherketone (PEEK), polyetherketoneketone (PEKK), a polymeric hydroxyethylmethacrylate (PHEMA), and polyurethane, any of which may be reinforced. Polymers used as bearing surfaces in particular may in whole or in part include one or more of cross-linked and highly cross-linked polyethylene. Example biocompatible metals include stainless steel and other steel alloys, cobalt chrome alloys, zirconium, oxidized zirconium, tantalum, titanium, titanium alloys, titanium-nickel alloys such as Nitinol and other superelastic or shape-memory metal alloys.

[00061] Terms such as distal, proximal, away, near, and the like have been used relatively herein. However, such terms are not limited to specific coordinate orientations, distances, or sizes, but are used to describe relative positions referencing particular embodiments. Such terms are not generally limiting to the scope of the claims made herein. Any embodiment or feature of any section, portion, or any other component shown or particularly described in relation to various embodiments of similar sections, portions, or components herein may be interchangeably applied to any other similar embodiment or feature shown or described herein.

[00062] While embodiments of the invention have been illustrated and described in detail in the disclosure, the disclosure is to be considered as illustrative and not restrictive in character. All changes and modifications that come within the spirit of the invention are to be considered within the scope of the disclosure.

Embodiments of the invention may include claims to:

1. A drilling system comprising:

a drill stop comprising:

a body;

a cannula coupled to a distal end of the body; and

a knob adjustably coupled to a proximal end of the body and movable relative to the body to alter the length of the drill stop;

wherein the drill stop includes a passage that passes through the cannula, the body, and the knob.

2. The drilling system of claim 1 wherein the cannula is an elongated member with a length greater than ten times its diameter.

3. The drilling system of claim 1 wherein the cannula includes a curved portion.

4. The drilling system of claim 1 wherein the cannula includes a window through which an indication of the amount of extension of a drill bit beyond a distal end of the cannula may be viewed.

5. The drilling system of claim 1 wherein the knob is configured to be rotated relative to the body to alter the length of the drill stop.

6. The drilling system of claim 1 wherein there is at least one set of stair steps between the body and the knob such that rotation of the knob relative to the body causes a following member to be moved along the stair steps to alter the length of the drill stop.

7. The drilling system of claim 6 wherein at least one set of stair steps is a portion of the body.

8. The drilling system of claim 6 wherein at least one set of stair steps is a portion of the knob.

9. The drilling system of claim 6 wherein one or more step landings of the stair steps includes an indention for receiving a portion of the following member to resist rotational movement between the body and the knob.

10. The drilling system of claim 1 wherein the knob is spring biased toward the body.

11. The drilling system of claim 1, further comprising an indicator system of the amount of potential extension of a drill bit beyond a distal end of the cannula on the knob and the body.

12. The drilling system of claim 1, further comprising a drill bit sized to pass through the drill stop.

13. The drilling system of claim 12 wherein the drill bit includes a marking visible through a window in the cannula that indicates the amount of extension of the drill bit beyond a distal end of the cannula.

14. The drilling system of claim 12 wherein the drill bit includes a bushing near a distal end of the drill bit to center the drill bit within the cannula.

15. The drilling system of claim 14 wherein the bushing is substantially spherical where the bushing is larger than an inner shaft of the drill bit.

16. The drilling system of claim 12, further comprising a drill with a drill chuck configured to couple to the drill bit, wherein the drill chuck includes a distal face configured to contact and be limited by a portion of the drill stop.

17. The drilling system of claim 1, further comprising a drill bit that is sized to fit within the drill stop and is restricted from moving beyond a predetermined point relative to the knob by a limiter portion of the drill bit configured to contact a limiting surface of the knob.

18. The drilling system of claim 17 wherein the limiting surface is near a distal end of the knob and the drill bit includes the limiter and the limiter is wider than a portion of the drill bit that passes through a distal end of the knob such that the limiter is configured to contact the limiting surface to restrict the movement of the drill bit distally relative to the knob.

FIG. 1

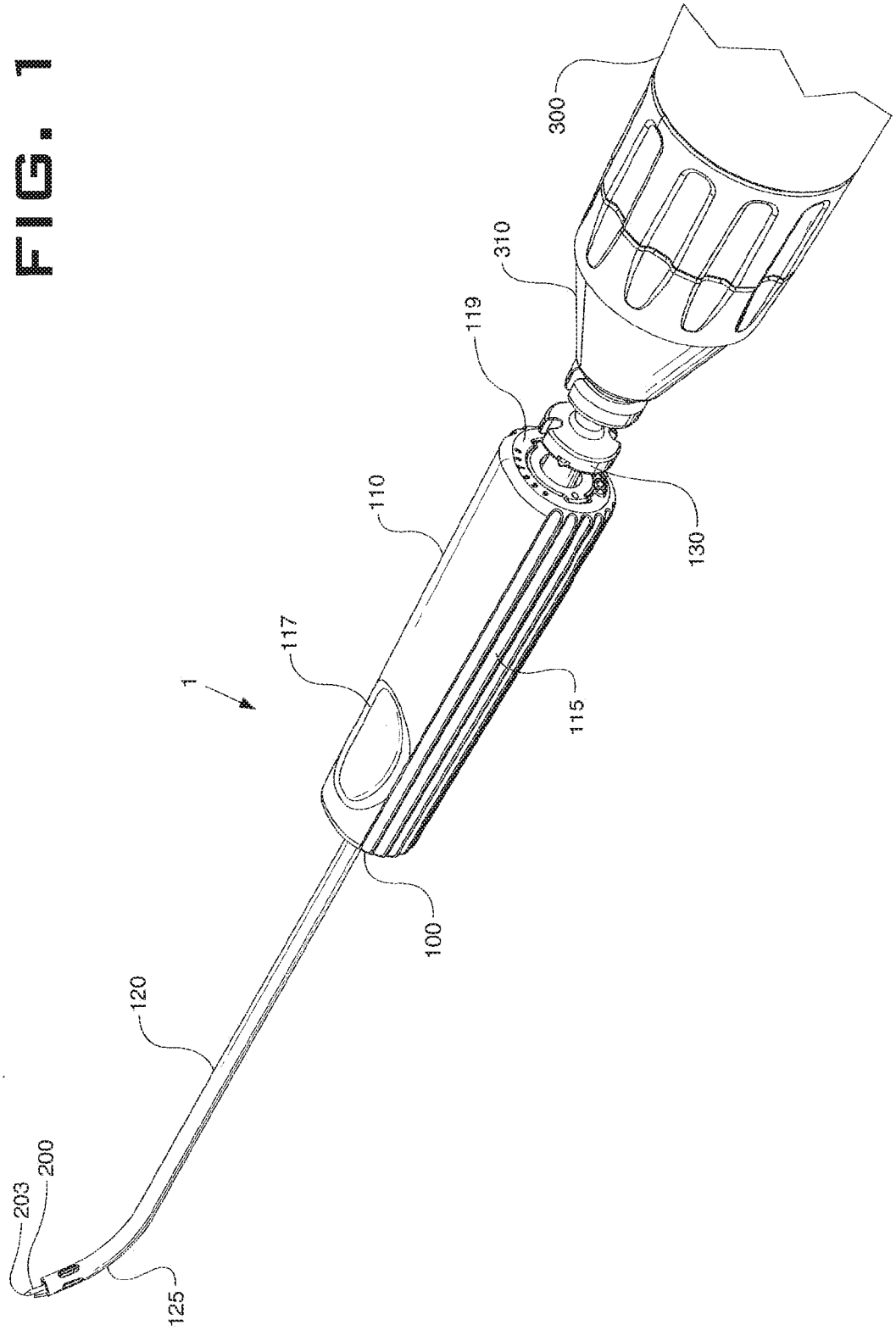


FIG. 2

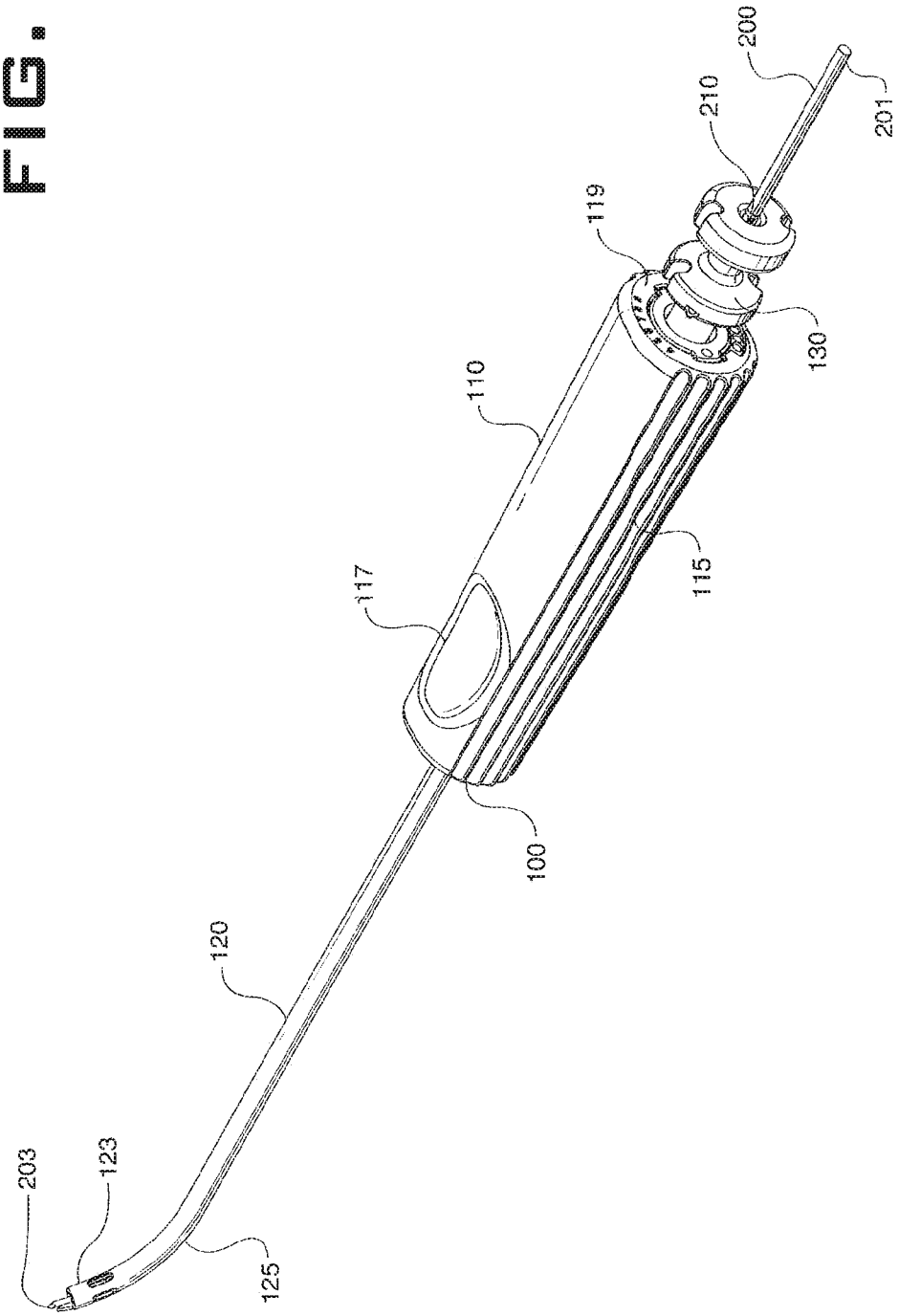


FIG. 3

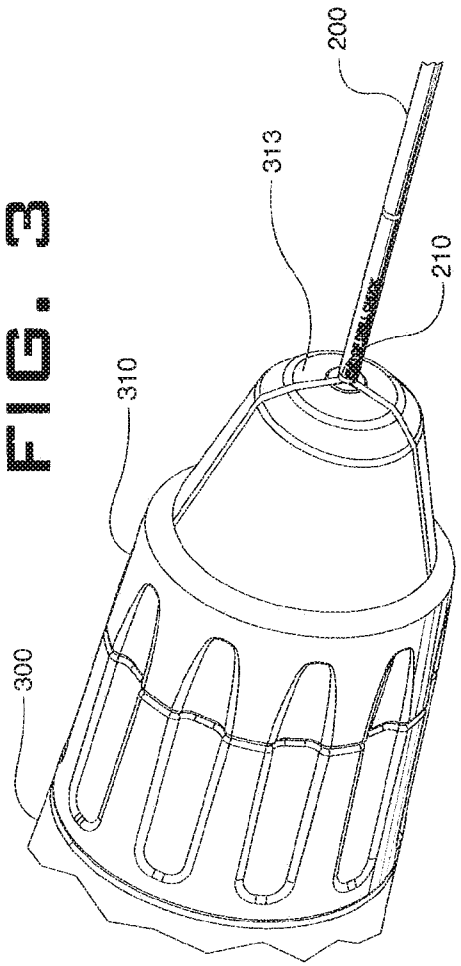


FIG. 4

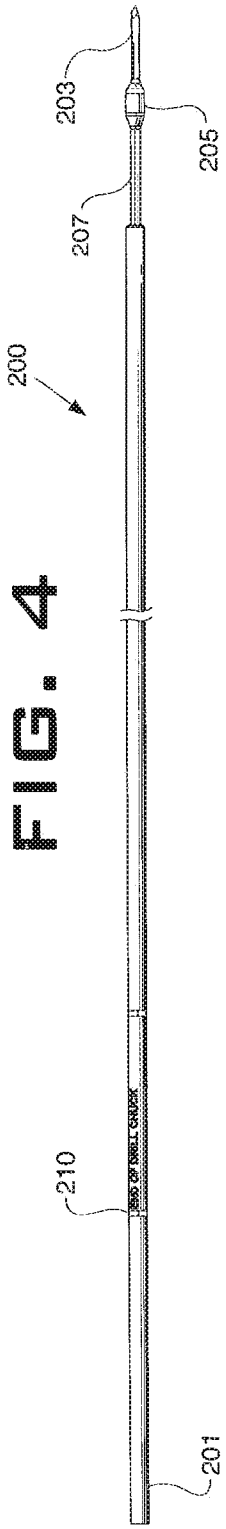
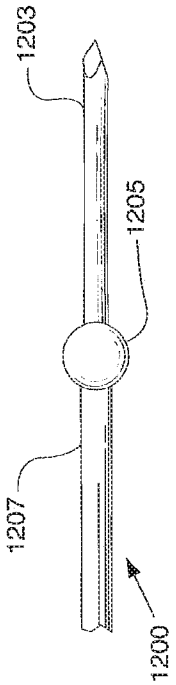


FIG. 4A



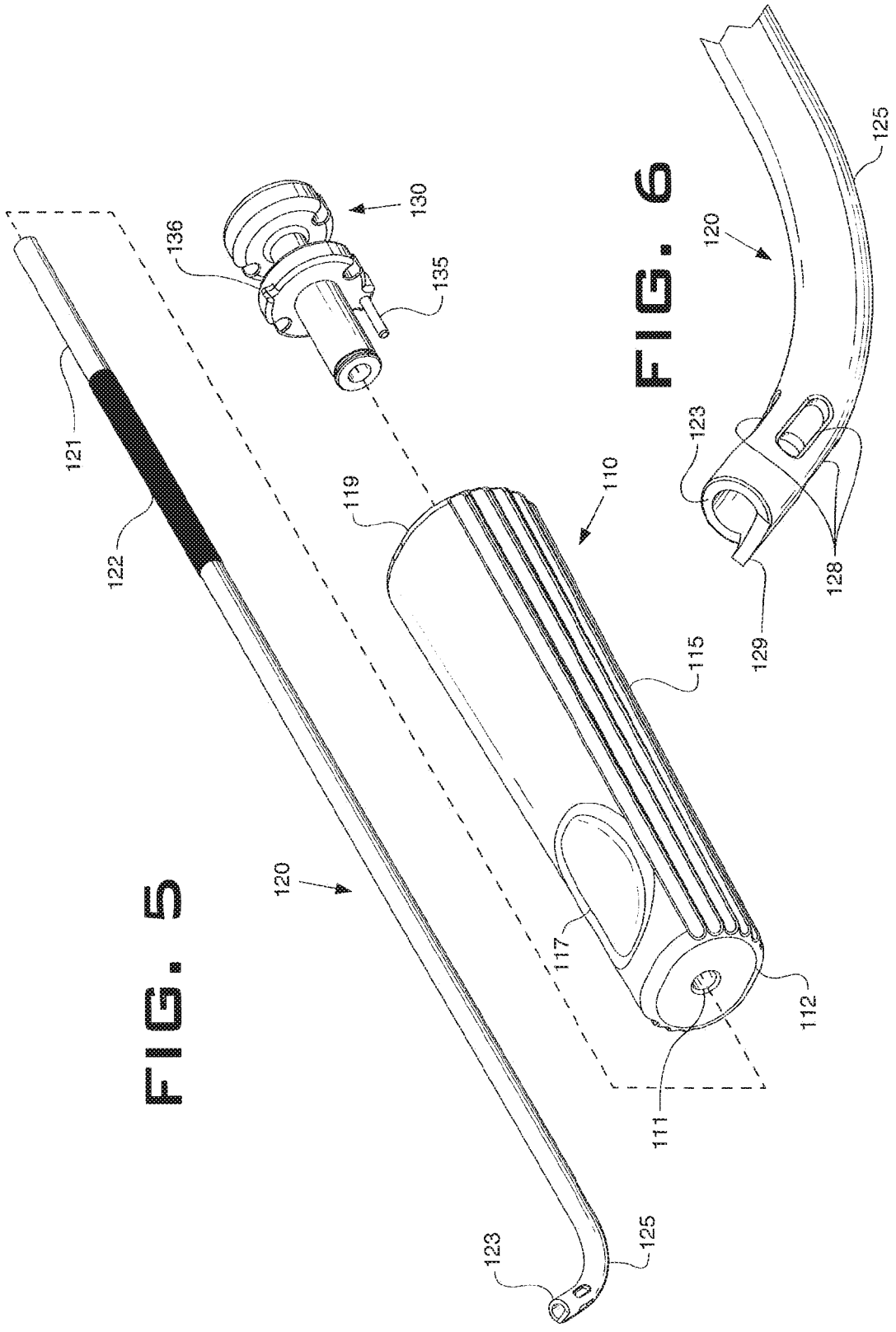

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FIG. 5

FIG. 6

FIG. 8

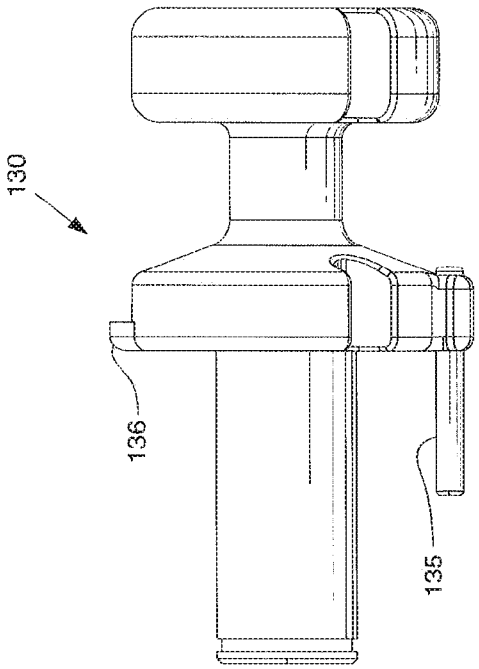
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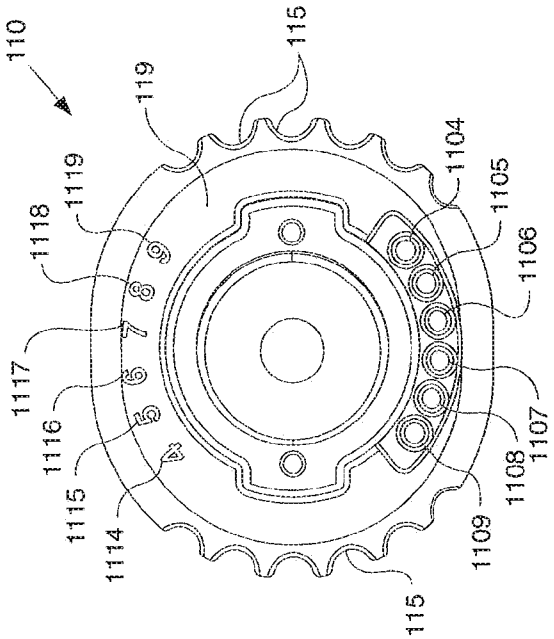
FIG. 7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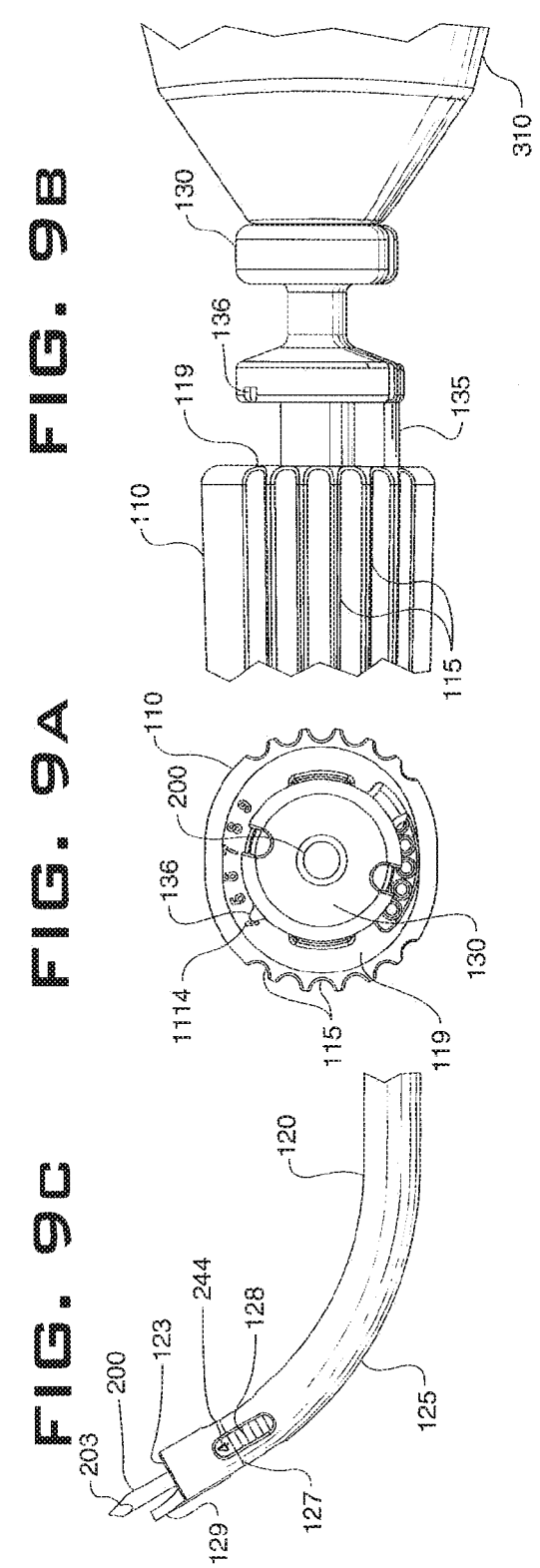

FIG. 9B

FIG. 9A

FIG. 9C

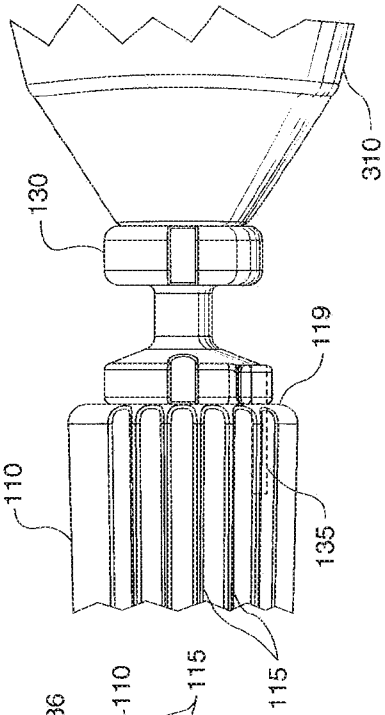

FIG. 10B

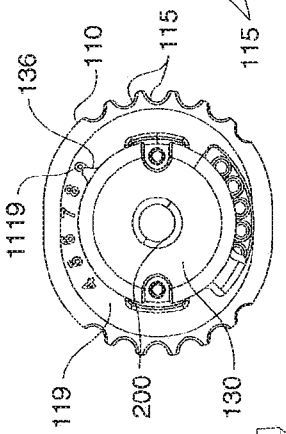

FIG. 10A

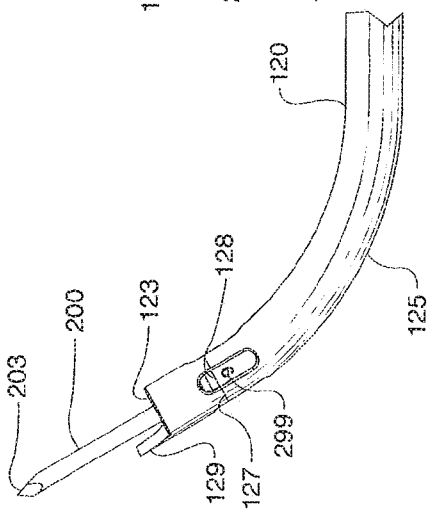

FIG. 10C

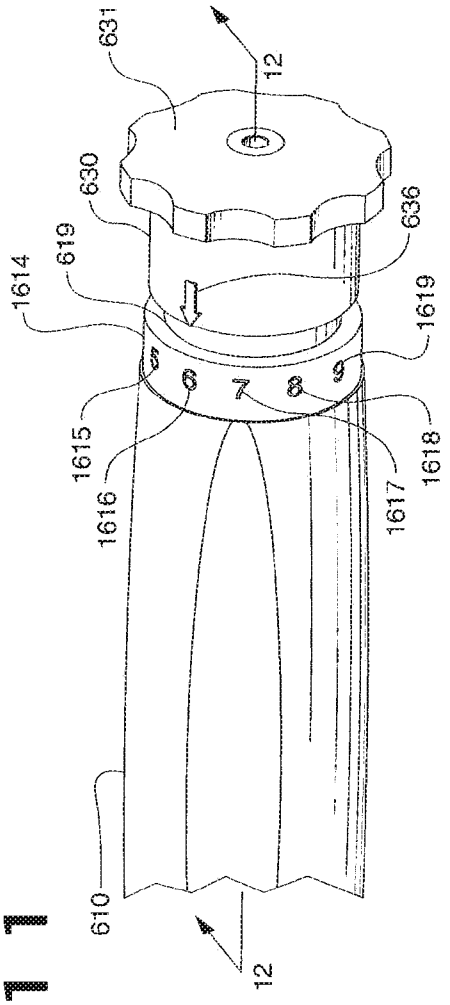
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FIG. 11

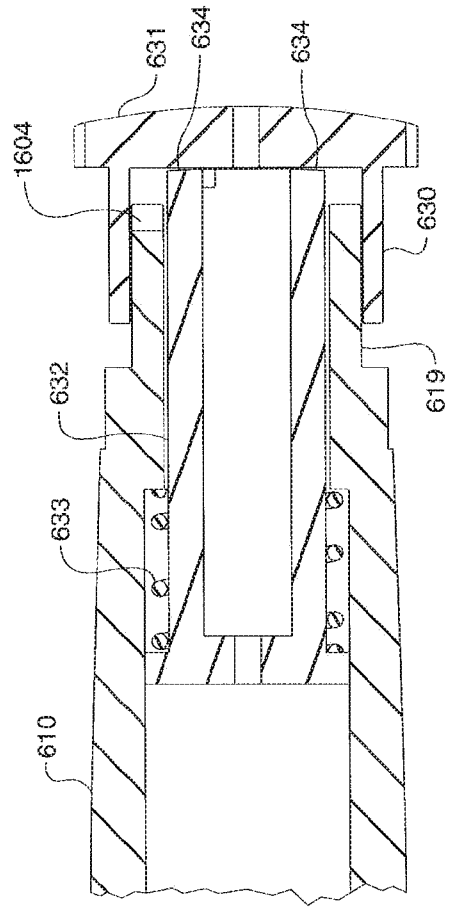
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FIG. 12

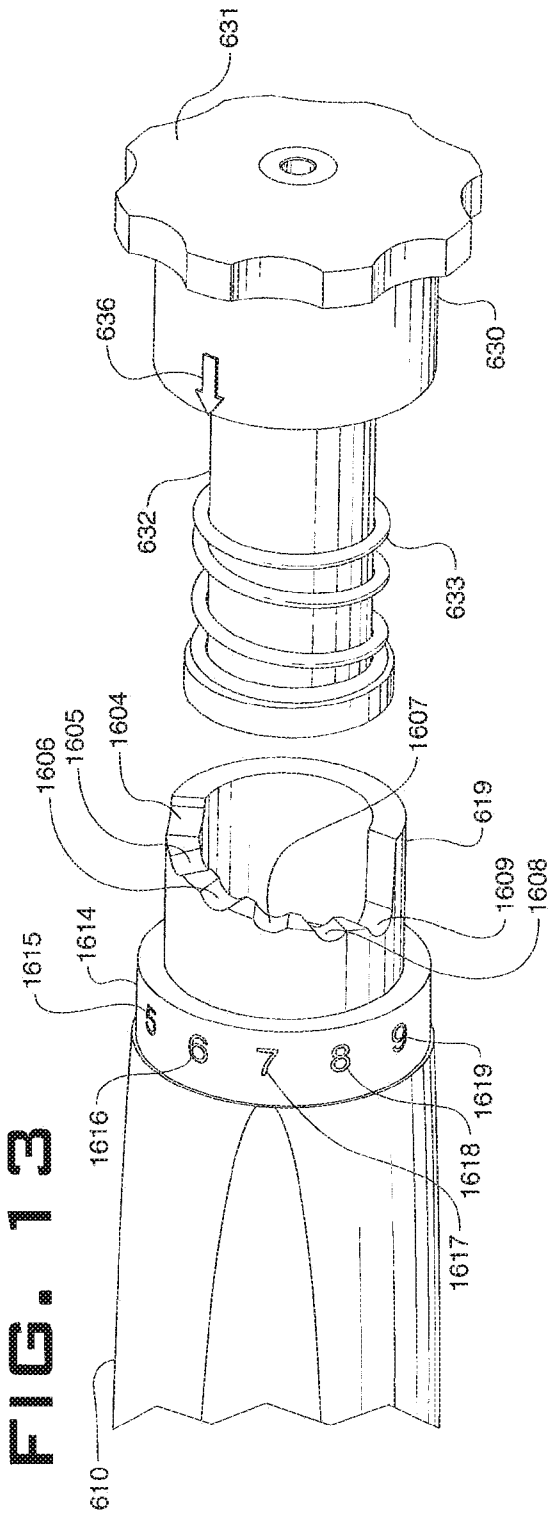
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FIG. 13

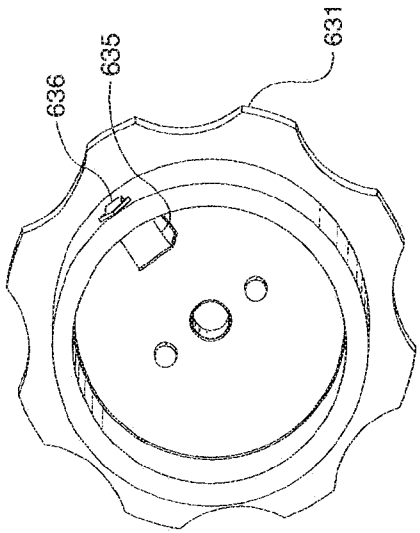
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FIG. 14

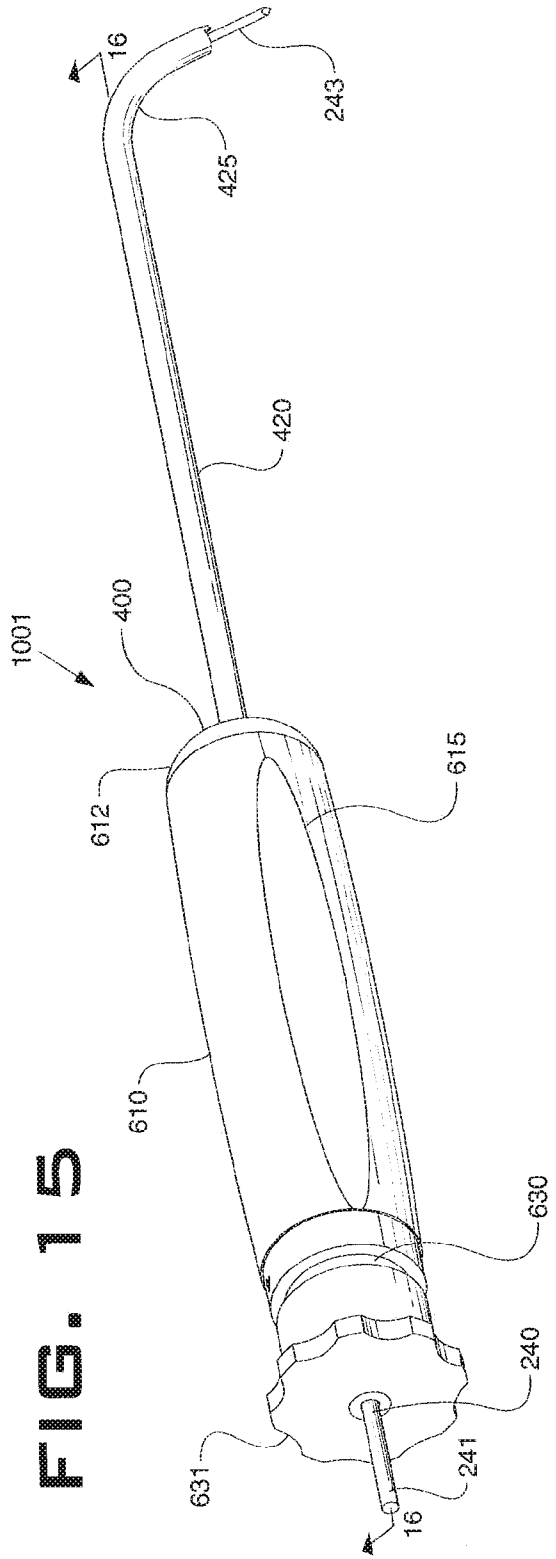
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FIG. 15

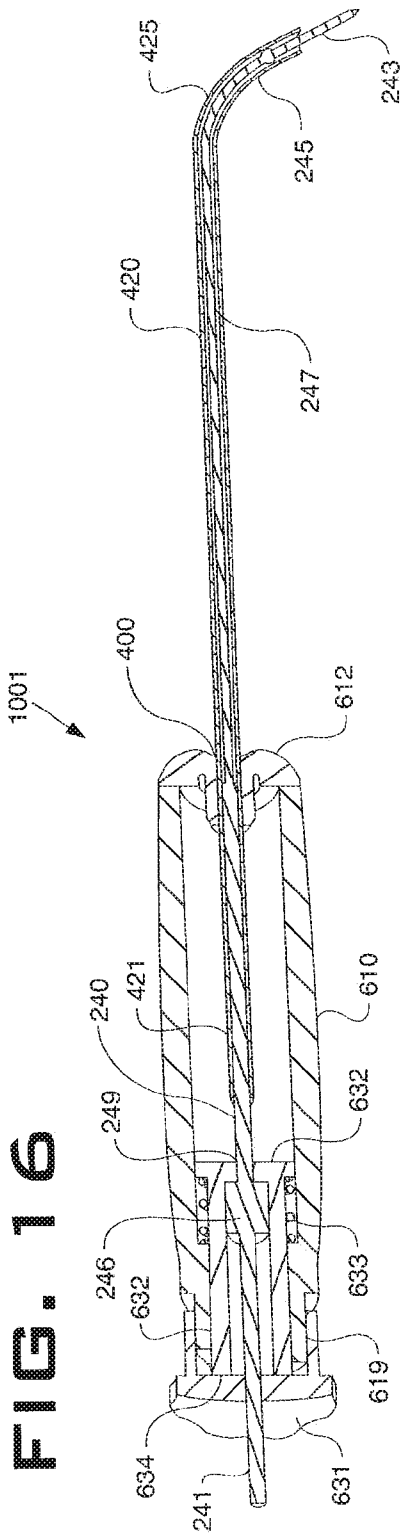
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FIG. 16

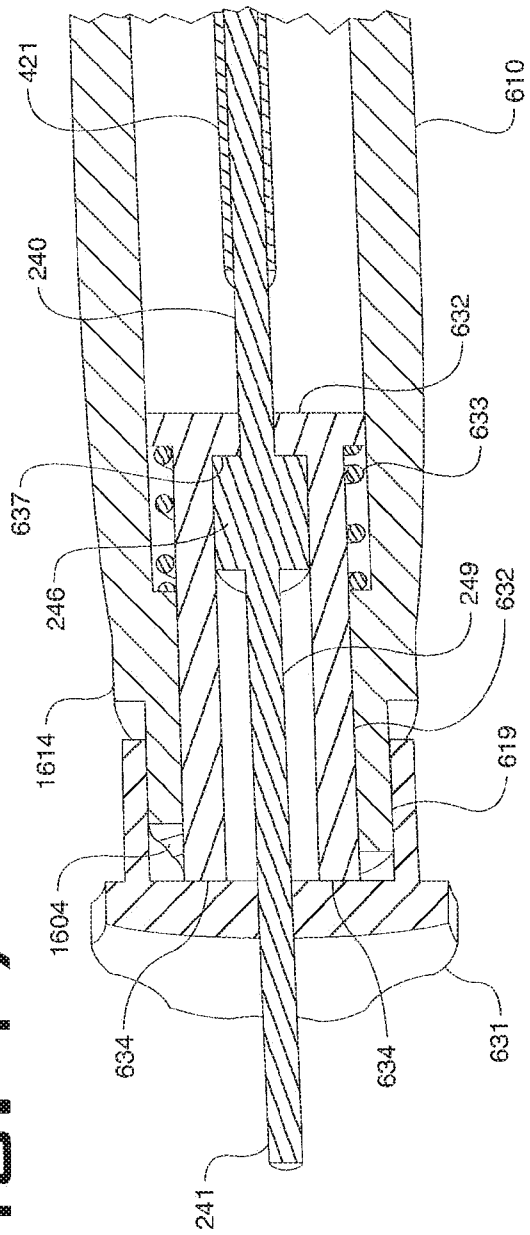
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FIG. 17

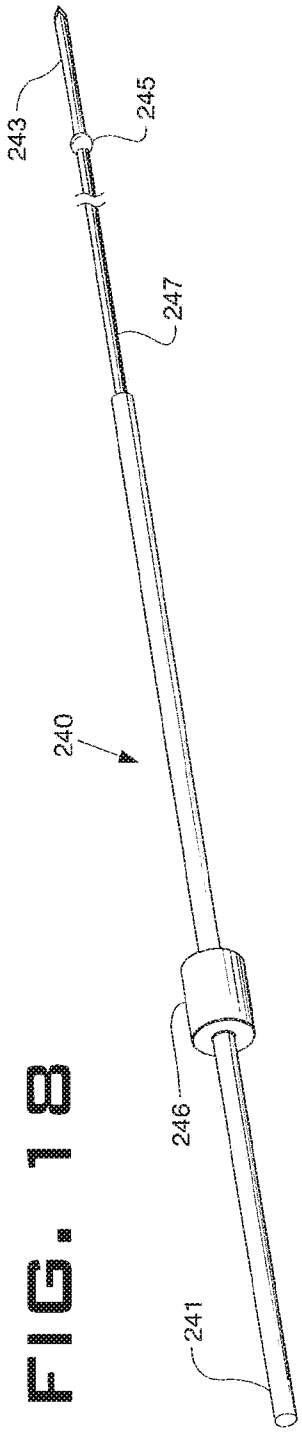
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FIG. 18

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/018590

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B17/16
ADD. A61B90/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2007/078463 A1 (MALANDAIN HUGUES F [US]) 5 April 2007 (2007-04-05) the whole document	1
A	US 2005/222575 A1 (CICCONE PAUL [US] ET AL) 6 October 2005 (2005-10-06) figures 1,2	1

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 April 2017	11/05/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Hamann, Joachim

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2017/018590

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US 2007078463 A1	05-04-2007	EP 1899893 A2	19-03-2008
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